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TRANSFER OF ANAESTHETIZED PIKE AND YELLOW WALLEYE

by

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Transfers of anaesthetized pike and yellow walleye were carried out during May, 1955, under the direction of the Canadian Wildlife Service, National Parks Branch, Department of Northern Affairs and National Resources, as part of a scheme of management of the fisheries of Prince Albert National Park, Saskatchewan.

Practically every known method of transportation has been used in transferring fish for stocking purposes. Both adult and small fish have been carried on horseback, in truck, and by boat, and have been flown in aircraft. Railway baggage cars have also been pressed into service. Transferring fish involves carrying tanks and equipment and water and ice, sometimes in great quantities.

In 1951, Jean-Paul Cuerrier of the Canadian Wildlife Service initiated the transfer of adult fish by anaesthetizing them with urethane (ethyl-carbamate) and moving them on crushed ice, packed in wooden boxes. In this way 1,100 lake trout (*Salvelinus namaycush*) were carried by air a distance of 20 miles from Wassegam Lake to Crean Lake, both in Prince Albert National Park. Seven flights with a Norseman aircraft were required. Only 10 per cent of the fish were lost in transit.

After being anaesthetized, the trout were placed in boxes in several layers, and covered, particularly the heads, with layers of chipped ice. At the destination the fish were revived in fresh water and released. A period of about one hour was involved in this transfer.

In the spring of 1955, the planting of adult yellow walleye (pikeperch or pickerel) (*Stizostedion vitreum vitreum*) in Sandy (Halkett) Lake received approval from National Park authorities. The transfer of fish by truck was feasible as the distances involved between Sandy Lake and the two possible sources of yellow walleye were 30 and 40 miles respectively. Plans were made to transfer the walleye under anaesthetization.

Preliminary Experiments

Since the time involved in this transfer was expected to be greater than during the previous experiment with lake trout, tests were undertaken to discover how long northern pike (*Esox lucius*) and yellow walleye could be held on ice in an anaesthetized condition. A number of each species were trapped in Mud Creek in conjunction with other trapping and marking experiments, and reserved in lots of 20 for a period of one to four days. When enough fish had been collected, a solution of 3 to 5 per cent urethane was prepared in a canvas relay tank set up on the shore of the creek.

Chipped ice, in pieces of varying size, was prepared. Wooden commercial fish containers about 30 inches long, 18 inches wide, and 7 inches deep were secured to hold the fish after immobilization. (See Figure 1.)



Figure 1. Canvas relay tank used to contain urethane solution and final layer of chipped ice being placed on box of fish.

Experiments with yellow walleye were carried out on May 2 and with pike on the following day. The water temperature at the time varied between 3.5 and 4.5° C.

The fish were placed in the urethane solution about 20 at a time and were allowed to remain there until they had fully relaxed and were "belly up". They were then taken from the solution and placed immediately in the fish boxes on a thin layer of chipped ice. (See Figure 2.) They were placed in the boxes ventral surface up to expose the gills more fully to moisture from the melting ice. Two layers of fish were again placed in each box with a layer of ice between the layers of fish, and a third layer of ice over the second layer of fish.

Great care was taken during the process of immobilization to ensure that all equipment was ready to handle the fish promptly after anaesthetization so that no fish would remain too long in the solution. It was also regarded as essential that the ice be in small enough pieces and not more than two layers of fish be placed in a box. This prevents crushing of the bottom layer of fish by excessive weight.

Five boxes of yellow walleye were prepared in the above way, each marked with a designated time for the reintroduction of the fish into water. The times of exposure to air for the five boxes were 1 hour, 2 hours, 3 hours, 4 hours, and 5 hours respectively, from the moment the fish were removed from the solution until they were replaced in fresh water. The fish in each box were marked by the removal of a fin in such a

way that the history of exposure was known. This was to guard against later confusion when fish with different exposure times mingled on liberation into fresh water. When packed, the boxes were placed in a half-ton panel truck and driven over park roads until the stipulated exposure time had elapsed.



Figure 2. Box of anaesthetized northern pike with ventral surfaces upward in layers of chipped ice, ready for shipment.

After the fish had been liberated into fresh water, continuous observation was maintained until they had recovered sufficiently to be able to balance themselves. They were considered fully recovered when they swam out of the holding area, one side of which was partially opened. (See Figure 3.)

The yellow walleye test was a success, and the following day three boxes of northern pike were prepared in the same way. The times of exposure to air for the three boxes were pre-set at 3 hours, 4 hours, and 5 hours respectively. The longer periods were used in view of the results obtained with yellow walleye. Time was measured, the fish were fin-clipped, and the methods of exposure and release in fresh water for the pike were the same as those used for walleye.

Observations and Results

It will be noted in the table on the next page that there was a loss of two yellow walleyes exposed for five hours but no loss of northern pike exposed for that period.

The results may be of importance to fisheries workers, as the method used makes it possible to transport fish long distances with the need of carrying only enough ice for the trip.

It may also be noted from the table that there is a variance of more than an hour in the length of time required for recovery. This probably results from differences in depth

of anaesthetization: some individuals may be more susceptible to the effects of urethane and some may have been longer in the solution than others. Pike generally recovered more rapidly than yellow walleye. Small fish were immobilized more quickly than large ones of the same species. Some large walleye took as long as 12 minutes. It took longer to anaesthetize northern pike than yellow walleye.

The results obtained for both species of fish are as follows:

Table I

Recovery of Northern Pike and Yellow Walleye after Anaesthetization

Number of fish Anaesthetized	Time of Exposure to air (hours)	Number of Recoveries	Percentage Recovery	Water Temp. °C.	Recovery time in Minutes
		Yellow	Walleye		
20	1	20	100	3.5	5 to 75
20	2	20	100	3.5	10 to 60
20	3	20	100	3.5	2 to 65
20	4	20	100	4.5	1 to 40
20	5	18	90	4.5	1 to 30
		Northern	Pike		
20	3	20	100	4.0	2 to 45
20	4	20	100	4.0	1 to 25
20	5	20	100	4.0	1 to 20



Figure 3. Yellow walleye which have been transferred and placed into fresh water. Some fish have regained balance while others are still "belly-up". Retaining area built of chicken wire.

From the table, it can also be seen that the longer the fish were kept on ice, the shorter the period of recovery. It was noticed that some fish held for 3 hours or more recovered almost as soon as they were released. Some fish removed by hand from the ice began movement as soon as disturbed. An upper time limit on the movement of fish by this method is probably imposed by the length of the period the fish will remain anaesthetized.

It was noted that some of the fish remained in the weedy shallows of the creek for some time after their escape from the retaining area, swimming slowly along the shore. However, none were found there the following morning and it was presumed they continued upstream to spawn. Evidence to this effect was obtained later, when three marked yellow walleyes were taken in a downstream trap across Mud Creek. The markings showed that they were from the lots which had been immobilized in ice for 1 hour, 2 hours and 5 hours, respectively. The fish were examined and were all found to be females which had released their eggs. There was no evidence of organic or systemic malfunction, and all tissue appeared to be normal.

Transfer of Yellow Walleye to Sandy Lake

With the knowledge gained from the above experiments, arrangements were made for the transfer of 300 yellow walleye to Sandy Lake. On May 20 and 21, gill-nets were used to capture 387 specimens in Crean Lake, of which about 90 per cent were believed to be male fish. Of this total, 39 died as a result of injuries received in handling and gill-netting. On May 21, the remainder (348) were moved by boat to Heart Lake, where they were held in a retaining area. The surface temperature of Crean Lake at the time of the removal of the fish was 8.0°C. The temperature of the water at Heart Lake was 10.5°C.

On May 22, two hundred anaesthetized adult yellow walleye packed on ice in eight wooden boxes were transferred about 40 miles to Sandy Lake in the back of a half-ton pick-up truck. With the excellent assistance provided by park personnel, the fish were out of water for periods of less than 2 hours. This was a shorter period of time than was originally expected. At Sandy Lake the fish were placed in a retaining area and allowed to swim away when able. All fish were marked by clipping a portion of the dorsal half of the caudal fin with pinking shears. On the following day, the remaining 148 fish were moved. Total losses during the two transfers were 15 per cent.

The losses encountered were not considered excessive but were high in view of the success obtained in the experiments earlier in the month. It seems that the higher loss resulted from a greater reduction in temperatures as walleyes fully acclimated at 10.5°C. were placed on ice in a medium near freezing point. In the earlier experiment, the corresponding temperature reduction was 3.5 to 4.5°C. A temperature drop of 10.5°C. may have been in excess of their temperature tolerance limit.

Of the yellow walleyes that survived and moved out of the holding area, 2 were recaptured, 3 and 5 days later, 2 miles from the site of release. Neither of these fish had spawned as yet. Both fish appeared to be in good condition and very active.

Literature Cited

- CUERRIER, J. P. 1952. *Transfer of Anaesthetized Lake Trout by Means of Aircraft*. Can. Fish Cult., No. 13, 1952, Can. Dept. of Fisheries.

EFFICIENCY OF YEAR-ROUND OPERATION OF TROUT COUNTING FENCES ON A SMALL STREAM

by

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Two counting fences of a type often employed in studies of populations of anadromous fish have been maintained for a number of years on Ellerslie Brook, Prince Edward Island. The effect of building a dam and forming a pond on the trout (*Salvelinus fontinalis*) population of this stream is being studied (Smith, 1951a, 1951b). Since the trout are tagged at Ellerslie Brook, and many are recaptured, there has been the opportunity to assess the efficiency of the counting fences. Operators of counting fences infrequently have had this opportunity.

The counting fences are maintained throughout the year on Ellerslie Brook. They are tended daily. All trout captured at the fences are tagged, as well as those of age I and older taken during annual population assessments in several sections of the stream. A numbered monel-metal strap tag, in circular form, is fastened around the mandible of each trout. The fork length in centimetres of all trout is recorded.

Large numbers of tagged trout have been recaptured. Records of recapture are obtained at the counting fences, from a creel census taken during the angling season of each year, during population studies in the stream, and by the commercial operations of smelt nets in the estuary of Ellerslie Brook. Accordingly, it has been possible to learn how many of the recaptured tagged trout were able to pass the counting fences undetected in their upstream and downstream movements. The extent to which this occurred and reasons for failure of the counting fences to capture all trout are discussed here. Data on these points are presented for the period from April 22, 1947, to September 30, 1951. Data on trout tagged after the latter date were not considered. Trout then tagged could still be in the population and subject to further recapture.

Ellerslie Brook

Ellerslie Brook is tributary to Malpeque Bay on the north shore of Prince Edward Island (Figure 1). It is a small spring-fed stream, which, with its tributaries, has an approximate length of six miles. The brook drains an area of farms and woodlots of about 10 square miles.

Records of the volume of water flowing from Ellerslie Brook became available after a dam was built and a pond formed in 1952. A chart presented by Anderson (1937) was used to estimate the volume of water discharged through the spillways of the dam. Daily observations were made and the data for 1953 and 1954 plotted in

Figure 2. These do not coincide in time with the data that are presented herein on the movements of tagged trout (1947-1951). However, they illustrate the range in flow of water that was probably encountered in the earlier years.

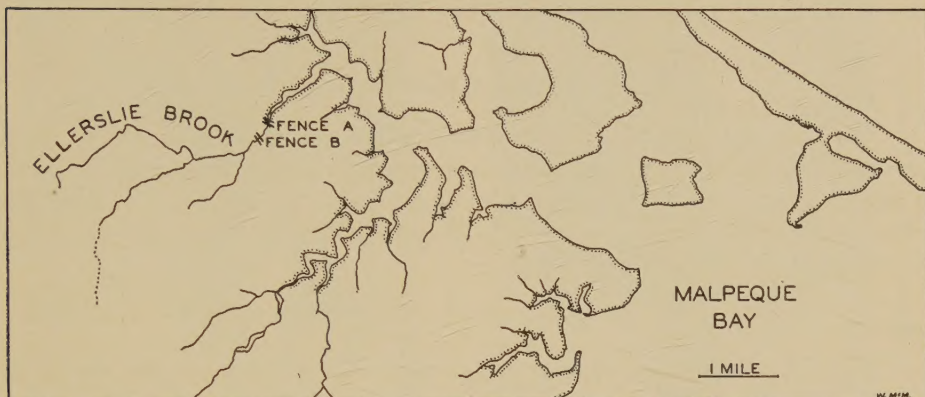


Figure 1. Map of the Ellerslie Brook area, Prince Edward Island.

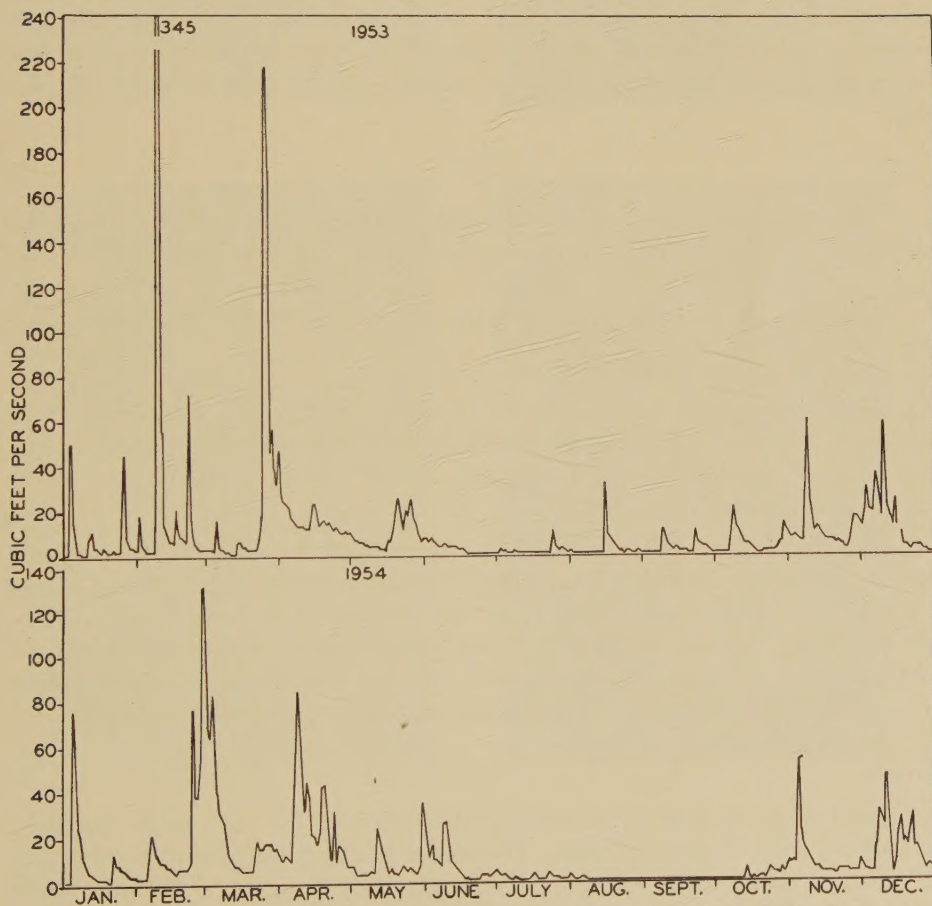


Figure 2. Volume of water discharged from Ellerslie Brook in 1953 and 1954.

The brook is subject to quite severe spates, but since the drainage basin is small they are usually of short duration. In our experience, the high flow of 345 cubic feet of water per second which was encountered on February 8, 1953, represents an extreme condition. Only on August 14, 1948, was a comparably heavy flood observed.

Ellerslie Brook Counting Fences

The counting fences capture trout as they move either upstream or down. They consist of a barrier and two traps, one to capture trout moving downstream, the other as they move upstream. The counting fences are illustrated in Figure 3. Except for minor modifications to meet conditions in Ellerslie Brook, the fences are of a design described and figured by White (1939).

Location.

Since June, 1946, a counting fence, designated A, has been maintained at the mouth of Ellerslie Brook, approximately midway between low and high-tide levels, to observe the movements of trout between the stream and estuary. In September, 1950, a similar fence, designated B, was installed 650 yards upstream immediately above a proposed pond site. Information has been obtained from the latter fence on the movements of trout, at first within the stream and later between the stream and the pond.

Traps.

The traps at the two fences are identical. Wood is used throughout with the exception of steel rods, one-quarter-inch diameter, spaced three-eighths of an inch around the lower three feet of the traps. To minimize possible injury of trout in the traps during spates, the upper parts are constructed of closely-fitting boards rather than of spaced steel rods. Each trap is five feet wide, nine feet long and six feet high with an entrance at one end 19 inches wide and 27 inches high. A funnel is attached to this opening and extends five feet into the trap. The funnel is six inches wide at its terminal end, with a seven-inch space between its lower edge and the floor of the trap. The top and bottom of the funnel are made of boards, and the sides are wood laths spaced three-eighths of an inch.

Each trap rests on a wooden platform which extends out three feet from the end and side of the trap exposed to the full force of the stream current. These extensions of the platform slope downwards. The pressure of water on these sloping surfaces aids in holding the trap in position. This type of construction lessens danger of washouts under the traps. Attendants enter the trap through a hatch on the roof to remove impounded trout. Stones are placed on the top of the trap for ballast.

Barriers.

The barriers are made up in panels of two sizes: four feet wide by six feet high, and four feet wide by three feet high. The smaller panels are placed in pairs, one above the other, at points where excessive stresses are likely to occur. The top panels can be removed if water pressure becomes too severe. On the original panels water



B. Fence A in winter.



D. Fence B in winter with frazil ice formation.



A. Fence A in summer.



C. Fence B in summer.

Figure 3. Ellerslie counting fences.

was strained through wood laths spaced three-eighths of an inch. To a large extent these have been replaced by one-quarter-inch diameter steel rods. These are stronger than the laths and provide a more efficient straining surface.

Difficulties Encountered in Operating Counting Fences

Storm tides.

On two occasions in the fall of 1947, once in the winter of 1951 and again in the winter of 1954 storm tides went over counting fence A. No damage to the counting fence resulted.

Freshets.

The water-straining capacity of counting fence A is approximately double that for B. (The total length of fence A is about 175 feet, and of B, 85 feet.) In consequence, less trouble has been experienced with freshets at the former. Counting fence A has effectively strained as much as 200 cubic feet of water per second but has broken down when subjected to 345 cubic feet. Counting fence B has strained in excess of 70 cubic feet of water per second but became inoperative on November 4, 1954, when a freshet of 60 cubic feet per second caused an accumulation of leaves on the barriers. Almost all of the breakdowns that occurred in the fences during freshets were the result of the accumulation of either ice or leaves on the screening panels. High water in itself has presented only minor difficulties in the operation of the counting fences. Attendants had to be constantly on the alert during freshets to see that the barriers were straining water properly.

Snow.

Snow on the barriers was undesirable since usually it resulted in the formation of slush that blocked the screening panels. The areas around the counting fences were protected considerably from drifting snow by snow-fences. Additional protection was had from buildings and trees. The snow was usually removed from the area immediately in the front and the rear of the fences (Figure 3B).

Ice.

(a) Surface ice. Much of counting fence A is located in shallow water that freezes down to the stream bed. After the first ice of the winter had been chopped away from the barriers no further difficulties were experienced. At counting fence B the depth of water is greater than at A. Here the ice was chopped away only with the onset of mild weather and possibility of freshets.

Three methods have been employed to prevent the formation of ice within the traps: (1) The traps were covered inside and out with tar paper, with a four-inch air space left between the two layers for insulation. (2) Snow was banked on occasion against the outside of each trap when the brook was frozen over. (3) During extreme cold each trap was heated by a small gravity-feed oil heater on a floating metal pan. The pan was kept level, as it adjusted to changing water levels in the trap, by guide wires that passed through rings on each corner of the pan and were fastened to the floor and roof of the trap. Only rarely was it found necessary to resort to heating.

If high water levels occurred during the annual spring breakup a few of the small panels were removed from the barrier and the broken ice was pushed through the fence.

(b) Frazil ice. Frazil is a fine spicular ice which may appear in a stream when the water is slightly supercooled, but is flowing too rapidly for a surface sheet to form (Barnes, 1928). It quickly agglomerates in coming in contact with solid objects, such as the counting fences in Ellerslie Brook. This phenomenon occurred in Ellerslie Brook in late fall and early spring. On numerous occasions a solid sheet of ice has been observed to form on the barriers within two hours after the first appearance of ice crystals in the water (Figure 3D). This resulted in the complete stoppage of water at the barriers and panels had to be removed to prevent the fences from being damaged.

Debris.

Debris on the screening panels slows down or stops the flow of water through the fences. Fallen leaves in the fall have been especially troublesome in this respect, particularly at counting fence B. Leaves have caused difficulties even at relatively low water levels. Raking the screening panels has proved effective, although at times involving much effort, for the removal of leaves and other small debris; large objects were either lifted over the fences or pushed through after panels had been removed.

Muskrats.

Muskrats have entered the traps through the funnels, especially in the fall and spring, and have on occasions gnawed holes through the laths on the bottoms of the traps in their attempts to escape. The trouble was minimized by replacing the laths with steel rods in 1950. They have occasionally, however, made holes through the wood panels on the barriers.

General Movements of Trout Through Counting Fences

Numbers of trout captured in traps.

The movements of trout, both tagged and untagged, through the two counting fences are shown in Table I in relation to years. It is from the recapture of the tagged trout that the effectiveness of the counting fences can be gauged. As noted, recapture was possible in the traps, by angling, during population studies and in smelt nets. Most recaptures were made in the traps and by angling. The data in Table I illustrate that a large number of the trout taken in the traps, especially the down traps, were untagged. These were being captured for the first time. However, these trout were tagged after their entry into the traps and provided data for this study by their subsequent movements.

Time of year.

Movements of trout at counting fence A in relation to season have been presented for the years 1946 through 1949 in progress reports (Smith, 1948, 1951a). Movements in 1950 and 1951 have followed the same general pattern at both counting fences. The prominent upstream movements of trout occurred in April, from mid-June to mid-July, and from mid-September to early January. Downstream movements have been most

Table I

The movements of trout through the Ellerslie counting fences.

Year	Counting fence A		Counting fence B*	
	Up	Down	Up	Down
1947 (April 1-December 31)	2491	1164	—	—
1948	1119	1747	—	—
1949	2320	3077	—	—
1950	1403	1427	—	—
1950 (September 26-December 31)	—	—	235	1424
1951 (January 1-September 30)	459	591	569	823
Totals	7792	8006	804	2247
Movements by tagged trout	4961	4163	706	698
Movements by untagged trout (first capture)	2831	3843	98	1549

* Counting fence B installed in September, 1950.

pronounced in May and from September to January. Within these several periods both upstream and downstream movements have varied from year to year in respect to the number of trout, date of occurrence and duration of the run. Few trout moved through the fences during the dead of winter or the height of summer.

Undetected Movements of Tagged Trout Through the Counting Fences

Extent of undetected movements.

There was a total of 10,528 movements by tagged trout through the counting fences after April 22, 1947, (when tagging of trout began) to September 30, 1951. This total includes those movements that were not detected, as shown by subsequent recaptures on the wrong side of the fences. There were 2,335 such undetected movements. They represented an error of 22 per cent in the trapping operations. It is assumed, without confirming evidence, that there was a comparable error in capturing untagged trout of the same length range.

This average error is minimal.

If any of the tagged trout made two or any even number of successive undetected movements through the fences, the error in trapping operations would be greater than that recorded. A correction to account for such movements would be difficult to determine since neither the movements of the trout nor the breaks in the fences occurred in a regular fashion. The tagged trout are subject to recapture at two counting fences, by anglers, in smelt nets and during population estimates in the stream. The likelihood of successive undetected movements is small. The actual undetected movements were somewhat greater than 22 per cent of the total known to have occurred, but probably not appreciably so.

In Table II the total number of movements by tagged trout and the number and percentage of those that were undetected are set forth in relation to the place and year of tagging and to the trap through which the escapement occurred. An examination of the data in Table II shows that the percentage of undetected movements through the fences, either up or down, varied markedly in respect to years and places of tagging. Such variation was not unexpected. There was no regularity—weather and rainfall were much involved—in the extent or time of the malfunctions of the fences.

Table II

Total and undetected movements by tagged trout through the Ellerslie counting fences

Place tagged and year	Total number of movements				Number of undetected movements with percentage in brackets			
	Fence A		Fence B		Fence A		Fence B	
	Up	Down	Up	Down	Up	Down	Up	Down
Fence A up—								
1947.....	320	633	0	0	49(15)	177(28)	0	0
1948.....	152	278	1	1	29(19)	54(19)	0	0
1949.....	148	336	2	6	12(8)	67(20)	0	0
1950.....	56	151	34	56	8(14)	25(17)	3(11)	2(3)
1951.....	20	51	89	24	4(20)	14(27)	14(18)	6(25)
Totals.....	696	1,449	126	87	102(15)	337(23)	17(13)	8(9)
Fence A down—								
1947.....	529	164	0	0	127(24)	36(22)	0	0
1948.....	1,050	453	1	2	319(30)	59(12)	0	0
1949.....	1,465	449	8	14	209(14)	107(24)	0	0
1950.....	335	47	25	30	64(19)	6(13)	5(20)	4(13)
1951.....	72	14	27	6	40(56)	7(50)	2(7)	2(33)
Totals.....	3,451	1,127	61	52	759(22)	215(19)	7(11)	6(11)
Fence B up—								
1950.....	5	24	5	54	4(80)	0	0	6(11)
1951.....	16	27	7	44	2(13)	12(44)	1(14)	23(52)
Totals.....	21	51	12	98	6(29)	12(24)	1(8)	29(30)
Fence B down—								
1950.....	301	704	213	80	158(53)	44(6)	19(9)	23(29)
1951.....	110	181	161	39	41(37)	45(25)	23(14)	20(51)
Totals.....	411	885	374	119	199(48)	89(10)	42(11)	43(36)
Stream—								
1948.....	139	239	1	2	37(27)	47(20)	0	1(50)
1949.....	79	152	3	15	5(6)	58(38)	0	0
1950.....	40	88	34	121	20(50)	13(17)	3(9)	6(5)
1951.....	124	172	95	204	4(3)	105(61)	5(5)	159(78)
Totals.....	382	651	133	342	66(17)	223(34)	8(6)	166(44)
Grand totals.	4,961	4,163	706	698	1,132(23)	876(21)	75(11)	252(36)

Relation to failures of counting fences.

Dates on which the counting fences could have failed to capture all or any of the moving trout and the reasons for these failures are shown in Table III. Dates on which trout were probably moving or not moving are indicated in this table. The

Table III

Dates on which counting fences on Ellerslie Brook could have failed to capture trout and reasons for failure

Dates on which trout were probably running	Dates on which trout were probably not running
I. Counting fence (A) at mouth of brook	
(a) Storm tides	
1947 : October 13, November 18	1951 : January 8 1954 : January 12
(b) High water during freshets	
1951 : January 5-9, May 30-June 8 : April 11-17	1948 : August 14-16 1953: February 8-March 13
(c) Frazil ice formation	
1949 : November 25, December 15, 24, 29 1950 : January 27 March 30, April 14, 16, 20	1949 : January 7-9 1950 : April 1, 2, 7 1954 : December 23
(d) Muskrat damage	
1948 : April 28, 30, December 2 1949 : April 24, 25, 28, May 4, June 23, July 3, October 26	1949 : April 19
II. Counting fence (B) on brook at head of pond	
(a) High water during freshets	
1950 : November 19 1951 : January 5-9, April 10-12, May 30, November 4 1953 : November 8 1954 : November 4	1953 : February 8-12, December 7, 10 1954 : February 27, December 10-11
(b) Frazil ice formation	
1951 : November 26-December 1 1952 : April 16-18	1952 : March 25-28, April 2, 10, 12, 13 1953 : February 10, 11, 22, March 25, December 17-19 1954 : March 6-8, April 4-15, December 23-28

basis of separation was whether or not trout were captured in the traps immediately before, during or immediately after the interruptions in the normal operation of the counting fences.

A good number of the failures of the fences to function properly occurred in the spring and fall when the major movements of trout, both upstream and down, also occurred. Periods when the fences were inoperative and the trout could have passed undetected were short for the most part. However, if a prominent movement of

trout and a break in the fences coincided, very considerable numbers of trout could pass unobserved in a short period. Probable instances of this character are illustrated in Figure 4.

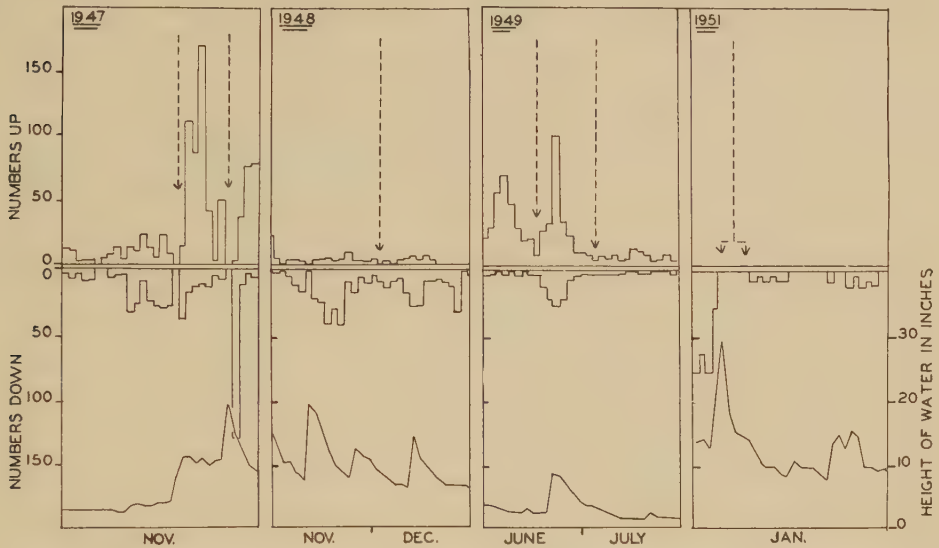


Figure 4. Recorded movements of trout at counting fence A in relation to malfunctions (indicated by arrows) of fence. 1947—Storm tide and freshet; 1948 and 1949—Muskrat damage; 1951—freshet.

In relation to length of trout.

The counting fences were not designed to capture trout fingerlings or small yearlings. Trout to about 11 centimetres (4 inches) fork length could pass through the spaces of three-eighths of an inch between the rods and laths on the barriers and traps. However, most trout over 10 centimetres in length would pass only with difficulty.

Undoubtedly small unmarked trout passed undetected between the rods and laths on the fences. It was impossible, however, to estimate their numbers. We have no evidence that, except for the occasional individual, trout fingerlings and small yearlings ran into salt water. The traps in fence A were lined with fine-mesh screening during part of the fall of 1948, until high water necessitated its removal. No trout below the lengths of those that were normally taken in these traps were captured. However, a different situation obtained at fence B. There movement through the fence only meant passing from one part of the stream to another. Possibly the greatest escape-ment of small unmarked trout, at times other than when breaks occurred, was through fence B.

In relation to the total movements by tagged trout through the fences, the highest percentage of those made undetected was by 12- to 13-centimetre trout (Figure 5). It was possible that some of the undetected trout in this length range passed through the three-eighths-inch spaces on the screening panels. We believe, however, that most of the undetected movements by the smaller tagged trout were through breaks in the fences. The greater proportion of the small trout moved in the fall-winter

and spring periods (Figures 6 and 7). It was during these seasons that breaks occurred most frequently in the counting fences (Table III). In contrast, the greater proportion of the larger tagged trout, among which there was a lower percentage of undetected movements, moved in late spring and early summer. This was a period of few breaks in the fences.

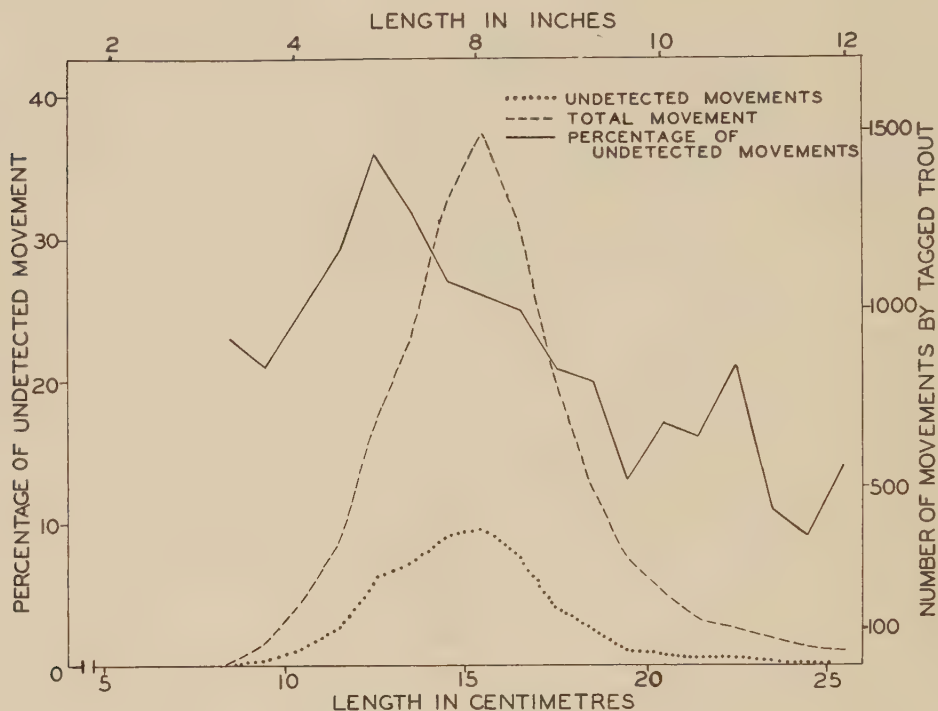


Figure 5. Relation between length of tagged trout and percentage of undetected movements.

Discussion

The extent to which trout moved undetected through the Ellerslie Brook counting fences is primarily of local interest. The data permit reasonably good corrections in arriving at the total number of trout of catchable size that moved upstream or down. However, more general interest may be attached to the fact that considerable escapement was encountered. Tagging of the trout permitted us to assess the escapement; this is usually not possible with trapping operations.

Our results were obtained on a small stream with the counting fences under close supervision. Year-round operation of counting fences on larger streams would incur increasing effort and difficulties, to the point where it would probably not be feasible.

Summary

Tagging of brook trout and their recapture showed that undetected movements through two counting fences held on Ellerslie Brook a small Prince Edward Island stream, comprised 22 per cent of the total made by tagged trout over a five-year period.

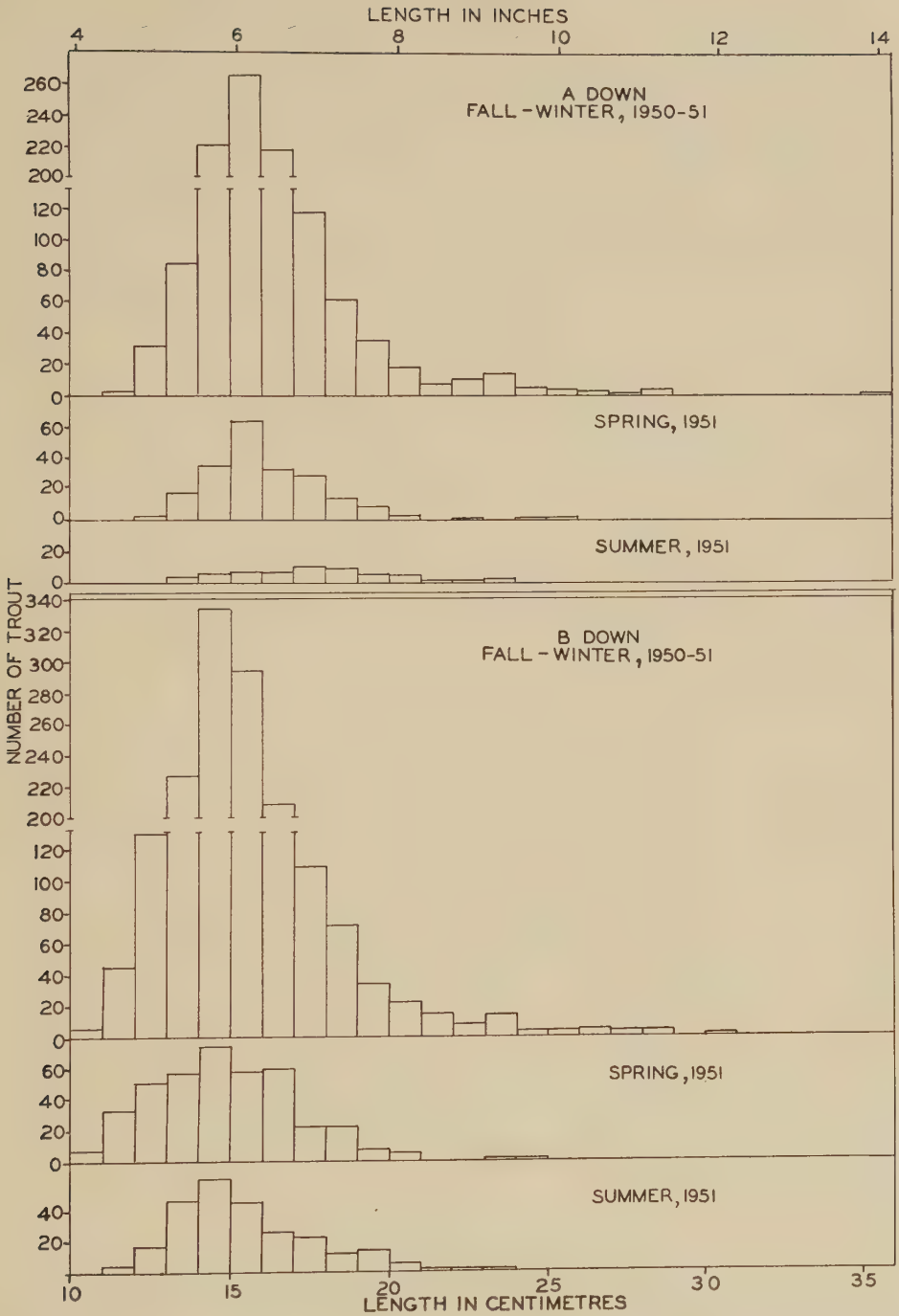


Figure 6. Length frequencies of tagged and untagged trout captured at counting fences when moving upstream.

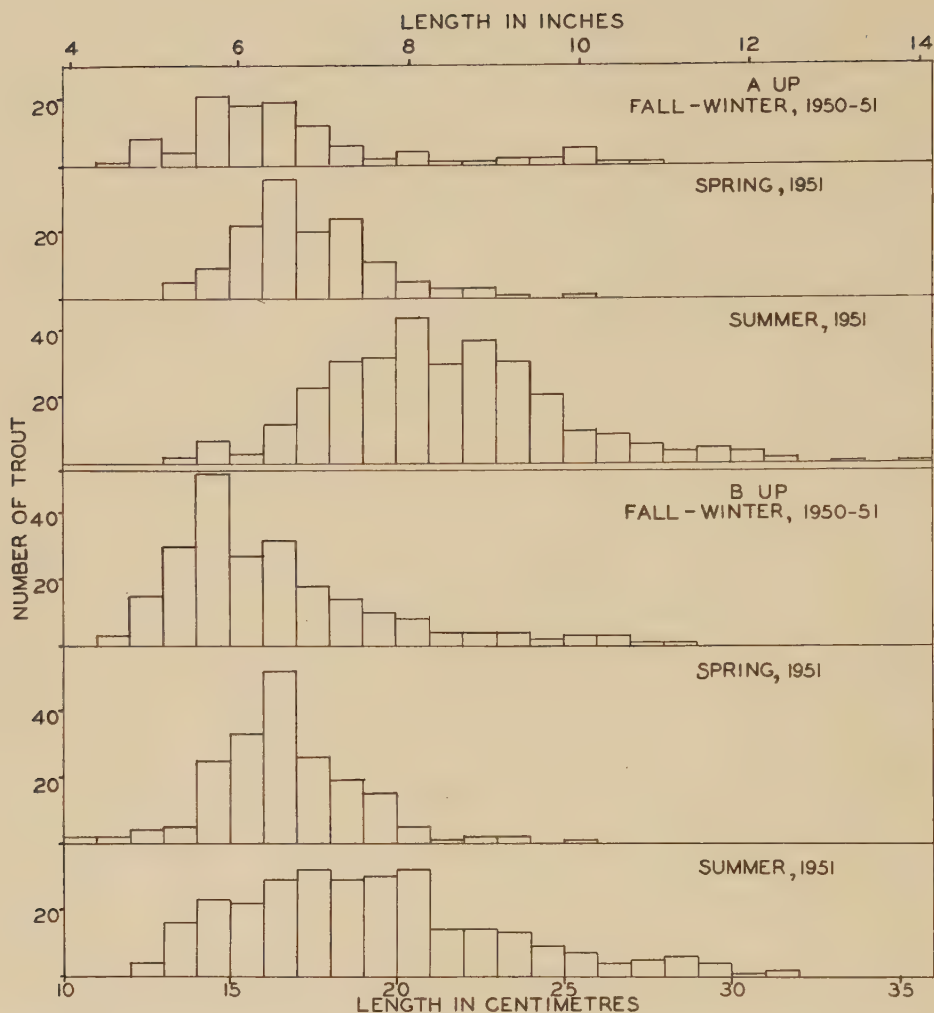


Figure 7. Length frequencies of tagged and untagged trout captured at counting fences when moving downstream.

The percentage of undetected movements varied irregularly in relation to season, year, fence and direction of movement. Freshets, accompanied by debris, frazil ice, storm tides and muskrats gave trouble in maintaining the fences in effective operation throughout the year.

Acknowledgments

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APPEARANCE OF LACTIC ACID IN THE BLOOD OF KAMLOOPS AND LAKE TROUT FOLLOWING LIVE TRANSPORTATION¹

by

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Mortality of fish during transportation is a common experience of the fish culturist. Often the cause of death is due to a lowered or complete lack of oxygen, or adverse temperature, or to a combination of these factors. Another cause of death is metallic poisoning (Carpenter, 1927) especially from zinc which may be brought into solution by the action of dissolved carbonates (Kleerekoper, 1940; Affleck, 1952). Baldwin (1948) found that carbon dioxide of metabolic origin caused the solution of zinc from the transportation container and death of fish during transportation resulted, possibly due to suffocation. Another type of mortality has been noted in rainbow trout, *Salmo gairdneri gairdneri* wherein the mortality appears from one to four days following the transportation (Horton, 1956). The term "delayed planting mortality" has been used to describe this type of death by biologists and fisheries workers from Oregon State, where observations were made upon the phenomenon at least 30 years ago. The symptomatology of delayed planting mortality, and a history of investigations in Oregon relating to the problem together with findings and recommendations for reducing the incidence of death are given in Horton's paper (1956). Considerable experience with the problem has been accumulated by the fisheries biologists in California (Wales, 1954; 1955). Miller (1951) has reported from Alberta on the mortality of cutthroat trout, *Salmo clarki*, following transportation and planting, and Newman (1955) has reported from British Columbia on the mortality of cutthroat and Kamloops trout, *Salmo gairdneri kamloops*, following transportation.

Horton (1956) states that delayed planting mortality in rainbow trout is preceded by three changes in behaviour. The first change is to a general state of uneasiness, wherein the hyperexcitable fish may be stampeded by any sudden stimulus. In the second state the fish appear to be unresponsive to visual stimuli, and to behave in an inco-ordinate manner. In the terminal stage the fish stops swimming and will either float to the surface or sink to the bottom. The fish appear to die while gasping, that is, from respiratory failure. Wales (1955) reported that some of the fish appeared to die from circulatory failure.

As a result of vigorous activity, the stores of glycogen in muscle are converted to energy available for the performance of work by the contracting muscles, and to various metabolites, the chief of which is lactic acid. The quantitative change of glycogen

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to lactic acid in muscle following stimulation has been summarized for fishes as well as for the rest of the animal kingdom by Ritchie (1928). Von Buddenbrock (1938) observed in certain marine fishes that had struggled to death in close confinement that the red blood cells were deformed and that the oxygen capacity of the blood was reduced, effects which he attributed to lactic acid of muscular origin. Huntsman (1938) has reported on overexertion as a cause of death of captive fish. Secondat and Diaz (1942) found that lactic acid increased in the blood of the tench, *Tinca tinca*, following muscular exercise, and in those fish wherein the lactic acid failed to subside, death occurred from 36 to 48 hours later.

Black (1955 a) has reported a high blood level of lactic acid (76 mg.%) for two-year-old Kamloops trout immediately following 15 minutes of vigorous activity, compared with 9 mg.% for the unexercised condition. This eight-fold increase in the Kamloops trout may be compared with the three-fold increase found in the tench by Secondat and Diaz (1942), wherein the resting level of 16 mg.% increased to 53 mg.% following exercise. Furthermore, unlike the usual conditions for mammals, wherein the decrease occurs within an hour (Johnson and Edwards, 1937) the lactic acid level of the blood in the Kamloops trout did not subside to approximate resting conditions until 6-12 hours of recovery (Black, 1955 b). Judged by electrocardiographic recordings, the heart stopped in two of eight particular experiments on fatigue in Kamloops trout (Black, 1955 b). In Kamloops trout, sockeye salmon, *Oncorhynchus nerka*, and lake trout, *Salvelinus namaycush*, a high sedimentation rate of blood was occasionally noted following vigorous exercise. Occasionally clotting within the blood vessels was noted in Kamloops trout. Mortalities were frequently observed in all of these salmonoids following fatigue, but death may have been due to cardiac damage from the hypodermic needle as much as to any other factor. Unfortunately, experiments were not carried out on control fatigued fish to show whether or not death may occur solely from changes following vigorous muscular exercise in fish which have not been subjected to any other experimental procedure.

It is contended that the various disturbances following muscular activity enumerated above may constitute the basis for delayed planting mortality in salmonoids.

Methods

The Kamloops trout used were two years old, and the lake trout were one and one-half years old. Both groups of fish were reared at the Summerland Trout Hatchery, Summerland, B.C., which is operated by the British Columbia Game Commission. The experiments were carried out at the same hatchery.

Twenty-five of each species of fish were transferred to the transportation tank which was mounted on a two-ton motor truck. The hatchery water supply, of artesian origin, was used to fill the tank. Two 2-cycle motors were used to operate the two water pumps which re-circulated and sprayed the water through galvanized pipes onto the surface of the water in the tank. The inside of the tank was coated with aluminum paint. The initial temperature of the water was 11.5° C. (52.7° F.); the initial oxygen tension was 145 mm. Hg. (95% saturated with air at 11.5° C.); and the initial free carbon dioxide level was 8 mm. Hg. (30 parts per million). To simulate conditions ordinarily encountered in transportation, the tank truck with the load was

driven over an uneven road for approximately one hour, which time was preceded and followed by one-half hour's travel on a relatively good asphalt road. The water temperature in the transportation tank at the end of the run was 16.7° (62.1° F.); the oxygen tension was 148 mm. Hg. (97% saturated with air at 16.7° C.); and the free carbon dioxide level had dropped to 3 mm. Hg. (10 parts per million). On return, the fish were transferred to a standard 4.88 meter (16-foot) hatchery trough covered over except for 0.9 meter (3 feet) at one end.

After the fish had been placed in the trough, a series of blood samples was taken with a hypodermic syringe. Each consecutive sample was obtained from the heart of a different fish. One portion of the blood was used for an estimation of the hemoglobin content, while a second portion was used for an estimation of the lactic acid content. The details of the methods employed are given in a paper by Black (1955 a).

Results and Discussion

The results for the Kamloops trout are presented in Table I and for the lake trout in Table II.

Table I

Blood levels of hemoglobin and lactic acid of two-year-old Kamloops trout at various times following transportation for two hours

Experiment Number	Time elapsed after run completed	Weight	Hemoglobin	Lactic acid
	Minutes	Grams	Grams per 100 cc	Milligrams per 100 cc of whole blood
1	4	128	11.2	51.0
2	8	202	13.3	47.4
3	12	80	10.0	51.9
6	24	172	11.6	47.7
7	28	270	11.3	26.0
10	40	280	11.4	37.0
11	44	193	11.1	13.4
14	56	152	10.9	18.5
15	60	130	12.2	37.4
18	72	257	11.7	17.5
19	76	291	11.1	16.5
22	88	156	12.3	9.5
23	92	182	13.7	7.1
26	104	310	6.1	5.1
28	112	232	8.4	9.5
30	120	203	10.6	4.7
32	128	152	15.9	7.9

In the values given in Table I, the lactic acid in the blood of Kamloops trout ranged from 47.4 to 51 mg. % during the first 24 minutes after the return to the hatchery, and then the blood level subsided erratically to approach the unexercised level after one and one-half hours of recovery. These data may be compared with unpublished experiments on the effects of 15 minutes of continuous and vigorous exercise in two-year-old Kamloops trout wherein the mean blood level of lactic acid increased from the

Table II

Blood levels of hemoglobin and lactic acid in one and one-half year old lake trout at various times following transportation for two hours

Experiment Number	Time elapsed after run completed	Weight	Hemoglobin	Lactic acid
	Minutes	Grams	Grams per 100 cc	Milligrams per 100 cc of whole blood
4	16	127	4.7	36.5
5	20	175	10.5	43.1
8	32	153	10.3	52.2
9	36	108	6.6	43.4
12	48	220	11.1	61.8
13	52	142	6.4	69.4
16	64	132	9.9	69.4
17	68	122	9.1	14.2
20	80	122	..	12.2
21	84	125	8.2	25.8
24	96	131	11.1	7.7
25	100	190	10.7	8.9
27	108	165	9.6	23.8
29	116	168	11.8	18.0
31	124	123	9.9	8.3

unexercised level of 9.2 ± 1.2 mg.% to 75.7 ± 4.7 mg.% for the exercised state. (The standard error of the mean is given after the mean.) At the end of two hours recovery after exercise, the value ascended to 117 ± 11 mg.% and did not subside for 8 hours, at which time the level of lactic acid in the blood was 20.4 ± 7.5 mg.% (Black, 1955 b). Thus the blood level of lactic acid attained during the two hours of transportation is 66% of that possible after 15 minutes of vigorous activity, and about 40% of the value for trout that had recovered for two hours following vigorous activity.

During the first hour following the transportation run, the blood lactic acid in lake trout increased from 36.5 mg.% at the end of the 16th minute to 69.4 mg.% at the end of the 64th minute, then decreased precipitously to 14.2 mg.% at the end of the 68th minute (Table II). These findings may be compared with unpublished data (Black 1955 b) wherein the blood level of lactic acid of lake trout increased from the unexercised level of 13.7 ± 5.2 mg.% to 91.8 ± 2.7 mg.% after 15 minutes of vigorous exercise. After two hours of recovery from exercise the blood level of lactic acid ascended to 177 ± 9 mg.% and did not return to the level of 27.9 ± 5.5 mg.% until 12 hours of recovery had elapsed. Thus, the blood level of lactic acid immediately after the transportation run in the lake trout was 40% of that observed 15 minutes after vigorous activity, and this changed to 45% of the level of 150 mg.% for one hour of recovery from vigorous exercise (Black, 1955 b).

There were also some changes in the sedimentation rate of blood, for both species of trout, and changes in respiration and behaviour in the lake trout following the transportation run. A rapid sedimentation rate was observed in certain blood samples. In Table I the low hemoglobin values in experiments 26 and 28 reflect a high sedi-

mentation rate. Sedimentation with consequent lowering of the hemoglobin level is offered as the explanation for the values obtained in the lake trout for experiments 4, 9, 13 and 20 (Table II). One sample of lake trout blood was rejected altogether because nothing but plasma appeared in the syringe. Where sedimentation occurred, usually the blood cells settled to the lower part of the syringe within the minute or less that was required to draw the sample from the heart. High sedimentation rates and variable hemoglobin values were noted following exercise in the fatigue studies for both the Kamloops and lake trout (Black 1955 b). Presumably the settling of cells from the blood plasma would lead to slowing of circulation in some vessels with stagnant anoxia following, and to an acute embarrassment of oxygen transport in other vessels where only the skimmed plasma would flow. These conditions would be followed ultimately by necrosis in the affected part.

Although no measurements were made, the lake trout appeared to be respiring very deeply and rapidly after the transportation run. As regards changes in behaviour, the lake trout did not swim about in the holding trough after the journey, nor did they try to evade capture. These changes correspond to changes observed in lake trout after they had been vigorously exercised for 15 minutes (Black 1955 b). The Kamloops trout were relatively active after the journey, and usually tried to evade capture.

When the observations on lactic acid levels, hemoglobin values and the sedimentation rate of the blood and of behaviour of Kamloops and lake trout following a simulated transportation run of two hours' duration are compared with similar changes following vigorous exercise for 15 minutes, it is concluded that the lactic acid production and other correlates of muscular activity may be implicated in the death of salmonoids following transportation.

If lactic acid production is a factor during transportation, then the alleged practice of adding seawater to a transportation tank containing freshwater when the fish appear distressed, may be explained. In recent studies on lactic acid production and removal from the blood following exercise, Black (1955 b) has found in yearling sockeye salmon that there is a significant reduction in lactic acid at the end of two hours' recovery in seawater as compared with freshwater. Furthermore, the salmon could be fatigued in seawater only with the greatest difficulty. These latter observations on the sockeye salmon are attributed to the buffering action of the seawater making possible an exchange of hydrogen ion, if not lactate ion as well, for other ions in the seawater bathing the gills. From these observations, it is suggested that the use of buffering and neutralizing additives to the transportation water be studied as a possible means of reducing the incidence of delayed planting mortality.

In this transportation run, adequate oxygen was provided. If the oxygen level should drop to one-third of air saturation, then the lactic acid production might increase two- or three-fold even at moderate activity, as has been demonstrated by Black (1955 b) for yearling Kamloops trout.

The implication that muscular exercise may be an important factor in transportation of live fish raises the question as to the advisability of conditioning fish to exercise, for the fish may be excessively exercised, preliminary to the transportation, from

seining the ponds. Conditioning fish to exercise before planting operations has long been practised by hatchery operators. It is recommended that fish so exercised be allowed to recover completely before being transported.

If muscular fatigue may be incurred immediately before as well as during the transportation run, then the advisability of holding the fish at the terminal end of the run should be systematically investigated. Black (1955 a) has reported that the swimming rate in yearling Kamloops trout is reduced from 16 kilometers per hour (10 m.p.h.) in the first three minutes of vigorous exercise down to 3.2 kilometers per hour (2 m.p.h.). Thus, even in fish that might escape delayed planting mortality, there is every likelihood that many would be subject to immediate removal by active predators in the planted waters. Fry (1955) has instituted the practice of ordinarily holding transported fish for 24 hours before releasing them.

While the use of anaesthetics has been recommended in transportation of live fish, Horton (1956) and Newman (1955) found in their experiments that the anesthetic sodium amyto1 afforded no protection against delayed planting mortality in their particular experiments. For a useful discussion of the subject the reader is referred to Horton's paper.

If zinc should be released from the container during transportation as Baldwin (1948) found, then the blood level of lactic acid would undoubtedly increase due to incomplete oxygen uptake, for lactic acid rises in humans in such pulmonary diseases as advanced pulmonary tuberculosis, chronic bronchitis and asthma (Peters and Van Slyke 1946).

Horton (1956) has found that there are two conditions that serve to control the delayed planting mortality, namely water temperature of 4.4° C. (40° F.), and the use of the Venturi aerators in the transportation tank. From preliminary and as yet unreported experiments it would appear that lactic acid which may accumulate in the blood following activity may be increased as the temperature is lowered (Black, 1955 b). However, it is rational to assume that the activity of the fish would be less at the lowered temperature (Fry, 1947). The use of Venturi aerators may not excite and perhaps may even reduce the activity of certain salmonoids; however, Kamloops trout likely would be stimulated by the use of the overhead spray. The overhead spray may also be important in oxidizing any organic exciting or modifying factor, such as the secretion from mammalian skin discovered by Brett and MacKinnon (1952) to be effective in altering the behaviour pattern of migrating salmon. This organic principle, probably of protein origin (Alderdice, Brett, Idler and Fagerlund, 1954) may be of importance in the transportation of all salmonoids and accordingly should be investigated.

The variability in mortality during and following transportation must be comprised of several factors including the initial condition of the fish, the excitability of the species in question, the excitation induced by the shape of the tank, the nature and duration of the transportation, the manner of oxygenating the water, the clearance of acid metabolites, temperature, metabolism of the fish, buffering capacity and pH of the water, freedom from toxic agents. To these factors and agents may be added the endogenous production of lactic acid from muscular activity.

Some of the implications of this study will be investigated further.

Conclusion and Recommendation

1. It is concluded that lactic acid from muscular activity may be a significant factor in causing delayed planting mortality in salmonoids.
2. It is recommended that fish be held for at least 24 hours at the planting site before being released, so that the transported fish may recover sufficiently to be able to swim at their maximum rate in order to cope with predators in the planted waters.

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NUMERICAL RELATIONS BETWEEN ABUNDANCE OF PREDATORS AND SURVIVAL OF PREY

by

W. E. Ricker

Fisheries Research Board of Canada

Correction

The following correction should be made in the above article which appeared in Issue No. 13 of *The Canadian Fish Culturist*. Starting at the ninth line from the bottom of page 6, the text should read:

This continues until all the thousand time-intervals have elapsed, at the end of which there are:

$$1,000,000(1 - 0.0008)^{1000} = 449,000$$

survivors (to the nearest thousand), or 44.9 per cent. What happens if the number of predators is doubled? In that event, during the first thousandth of the season twice as many fish will be eaten, i.e., 1,600, leaving 998,400. In the next thousandth the fraction eaten is likewise double, namely 0.0016; multiplied by the number of survivors this gives 1,597; and so on. At the end of the season $1,000,000(1 - 0.0016)^{1000}$ survive, which is 202,000, or 20.2 per cent.

Thus doubling the number of predators doubles the instantaneous mortality rate (which is true generally), but it increases the actual mortality from 55.1 to 79.8, or by only 45 per cent of its original value (which is true of only this particular example).

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1956